NSS/HP-1740.4
13 AUGUST 1976

NASA MEDIUM WEIGHT PRESSURE VESSEL SAFETY STANDARD

OFFICE OF SAFETY
AND
ENVIRONMENTAL HEALTH

National Aeronautics and Space Administration

WASHINGTON, D.C.
20546

E R R A T A S H E E T

1. Page 8, paragraph L., line 4: insert the word “for” in between “but” and “which.”

2. Page 9, paragraph 1.: delete last word.

3. Page 9, paragraph 2., last line: change spelling of word "substialyes" to "substantiates."

NASA MEDIUM WEIGHT PRESSURE VESSEL SAFETY STANDARD
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I. PURPOSE

The purpose of this standard is to provide requirements to control the design, fabrication, test, operation, certification, and recertification of medium weight pressure vessels.

II. SCOPE

Pressure vessels covered by this standard are those having a safety factor within the nominal range of 2.5 through 4.0. Industrial standards such as the ASME Boiler and Pressure Vessel Code, which have provisions for medium weight pressure vessel design and certification may be used in lieu of this standard when appropriate. This standard is applicable to flight operations. It is also applicable to ground operations directly associated with flight or where simulation of flight hardware or weight reductions are necessary for test purposes. Because of generally higher costs of pressure vessels built and operated to this standard, it generally should only be used for applications which cannot be performed by vessels meeting the ASME Boiler Code. Pressure vessels designed to the requirements of this standard will be documented and controlled by means of an Operations and Configuration Control Plan (OCCP). Systems which are connected with medium weight pressure vessels for either operational, test, or maintenance purposes shall be compatible with the pressure vessel constraints imposed by this safety standard; however, the design requirements for these systems are not covered herein. Flightweight pressure vessels having a design factor of safety less than 2.5 are not covered by this standard. Such vessels shall be designed, fabricated, and operated to the requirements of NASA Aerospace Pressure Vessel Standard NSS/HP-1740.1.

III. DEFINITIONS

Design Burst Pressure - The pressure at which the pressure vessel should burst if all of the specified design tolerances are at their minimum values.

Maximum Allowable Working Pressure - The maximum pressure which can be applied to a pressure vessel by the pressurizing system with the pressure regulators and relief valves at their upper limit and with the maximum fluid flow rate.

Medium Weight Pressure Vessel - A pressure vessel, either metallic or non-metallic, which has a factor of safety within the range of 2.5 to 4.0.

Operating Pressure - The maximum static pressure at which the pressure vessel will be operated which does not require operation of burst discs, relief valves, pressure regulators, etc.

Proof Factor - The factor by which the maximum allowable working pressure is multiplied to give the proof pressure.

Proof Pressure - The pressure to which pressure vessels are subjected to in order to meet acceptance requirements of the customer and in order to give evidence of satisfactory workmanship and material quality. Proof pressure is the product of maximum allowable working pressure times the proof factor.

Proof Test - The test at proof pressure which will give evidence of satisfactory workmanship and material quality.

Qualification Test - A test or series of tests conducted on an actual typical pressure vessel which establishes that the general design and fabrication are acceptable for the intended use.

Verification Test - A proof test or other tests or inspections to establish the integrity of a pressure vessel after it has been subjected to some adverse condition or after some specific period of operation or storage.

99% Exceedance, 95% Confidence Level - The material value which will be exceeded in 99% of the measurements made, provided the distribution function in 95% of the cases. (Ref to MIL HDBK 5B, "A" Values)

Factor-of-Safety - The factor by which maximum design operating pressure is multiplied to obtain design burst pressure.

Recertification - A verification of the pressure vessel's suitability for safe service based on periodic inspection, testing, and analysis.

IV. IMPLEMENTATION

Any pressure vessel whether intended for flight or ground use, certified to the requirements of this standard will be considered satisfactory for use and meets the intent or requirements of other applicable codes or standards.

V. OPERATIONS AND CONFIGURATION CONTROL PLAN (OCCP)

All vessels, existing or new, which are certified to the requirements of this standard shall have an Operation and Configuration Control Plan (OCCP). This OCCP will contain all restraints necessary for the operational life of the vessel. The OCCP should contain a

summary of the criteria used in performing the tasks specified in Sections VI.A. through VI.L., below, and the means for documentation and recovery of the results. The OCCP shall also provide for the requirements of NHB 1700.6.

VI. CONSIDERATIONS NECESSARY FOR PRESSURE VESSEL CERTIFICATION

A. Design Considerations

The design shall consider and provide for pressures, temperatures, internal and external environments, and stresses whether imposed by internal or external loads or other sources of stress to which a vessel may normally be exposed. The internal and external liquid and gaseous environments to which the vessel will be exposed including cleaning, flushing, storage, and service use shall also be considered. The cumulative static and dynamic loading and the rate of application of loads anticipated in the various phases of service life shall be defined and accounted for. The following factors shall be considered.

1. The explicitly defined model upon which the fatigue life spectrum is based.

2. The frequency of application of the various types of loads, load levels, and environments.

3. The environmentally induced loads.

4. The environments acting simultaneously with loads in their proper relationships.

5. The prescribed service life requirements.

6. The design spectra to be used for both design analysis and qualification testing.

7. Thermally induced stresses or changes in material properties which are factors in the design of each pressure vessel.

8. A complete internal pressure-time-temperature history of the vessel and the internal and external liquid and gaseous environments to which the vessel will be exposed during test, cleaning, flushing, storage, and service use shall be considered in the design.

9. Limited local yielding caused by stresses resulting from existing manufacturing discontinuities shall be permitted at the proof-test pressure level. General yielding shall not be permitted at the proof-pressure level unless the pressure vessel is designed to accommodate it.

B. Materials

Materials, properties, or characteristics used in design or analysis shall be taken from a reliable source of data such as MIL-HDBK-5, MIL-HDBK-17A, or be determined by test. Material mechanical properties shall be statistically significant at the 99% exceedance, 95% confidence level. Values shall be obtained for both parent and weld materials where metals are used.

Note: Uniformly recognized test procedures (ASTM, ASME, ASM, etc.) shall be employed for determination of material properties. The test specimens and procedures utilized shall provide test data for the intended application. Test procedures shall be approved by cognizant authority. Property values shall be obtained on a sufficient number of material lots to permit evaluation of lot-to-lot variation. Where lot-to-lot variation has not been experimentally established, data shall be obtained for each lot used in the construction of the pressure vessel.

C. Analyses

Structural, stress, fatigue, and Fracture Mechanics type analyses shall be performed to verify the structural adequacy of a pressure vessel. Where adequate theoretical techniques do not exist or where experimental correlation with theory is inadequate, the analyses shall be supplemented by tests (see Par. E. below). The following analyses shall be provided as applicable:

1. Analyses of static and dynamic loads and thermal stresses.

2. Fatigue life analyses

3. Definition of test requirements including materials tests, structural development, qualification tests, and proof tests.

4. Where fracture properties and characteristics are known for the material of a pressure vessel, fracture analyses may be utilized to further define or supplement conventional analyses where prudent and necessary.

D. Proof Tests

Each pressure vessel shall be designed as a goal to accomodate a proof test pressure of 1.5 times maximum allowable working pressure. As a minimum, the requirements of ASME Code Section VIII, Div. 1 or 2 shall be met for metallic vessels. For non-metallic vessels the requirements of ASME Code Section X shall apply.

E. Tests

Design development tests shall be performed to confirm material/fluid compatability, design approach, manufacturing processes, and service life. Qualification tests shall be conducted on production hardware to demonstrate the structural adequacy of the design and the acceptability of the manufacturing processes. These tests shall include a demonstration of resistance to cyclic fatigue greater than four times the expected service requirement.

All proof tests are to be considered hazardous and conducted remotely. Suitable facilities shall be utilized during development, qualification, and acceptance testing. A preproof-test inspection shall be performed to establish the initial condition of the structure. It is preferred that a nonhazardous liquid pressurizing medium be used in proof testing. The use of a compressible gas for proof testing shall be utilized only with approved procedures to insure a safe and adequate test. Postproof-test inspection shall be mandatory at a level which shall ensure that no flaw or defect which survives the proof test shall grow to critical size during the expected service life of the vessel.

The proof test stress shall be no greater than 90% of yield strength for the material used. As a minimum, the proof test shall apply pressures and/or stresses which exceed allowable working limit loading in critical sections of the test article. Where a proof test is conducted at a temperature different from the critical design condition, suitable correction shall be made to the proof loading to account for the difference in structural strength and material characteristics at the two temperatures. Where full proof testing is not a practical operation, non-destructive tests (NDT) should be used as an adjunct to establish the level of confidence necessary to verify the pressure vessel's suitability for certification.

F. Operations, Maintenance, and Certification

The requirements for operations, maintenance, and certification must be defined in the OCCP. The following items must be considered for inclusion in the OCCP:

1. The inspection intervals required for the pressure vessel based on fatigue analyses and the results of development and qualification test.

2. The probable location and character of defects expected for the pressure vessel scheduled for periodic inspection.

Defect characteristics should be based on total experience gained over the development program, including data derived from fabrication, structural development, and structural qualification tests.

3. Inspection procedures to reliably detect structural defects under the conditions of use for periodic inspection.

4. The requirements for environmental conditioning or control needed for physical and corrosion protection (both internal and external during maintenance or storage.

5. The requirements for periodic reproof tests and the conditions under which reproof or reinspection are required. This shall include the identification of any inadvertent violation of design constraint.

6. Written procedures for operation of the pressure vessel and its associated system. These procedures shall be consistent with safety requirements and personnel exclusion requirements of the facility conducting the operations. As a minimum they shall contain requirments for system safety hazards analyses to insure compatibility of the pressure.

7. A record system which accounts for all maintenance operations, tests, and inspections performed with or on the pressure vessel.

8. A procedure for pressure vessel identification and certification which as a minimum provide at or on the pressure vessel the maximum allowable working pressure and a method to trace the pressure vessel records.

G. Storage

When pressure vessels are to be put into storage, the following must be provided for:

1. Prevention of mechanical damage, such as scratches, dents, dropping, etc.

2. Protection against exposure to adverse environments (both internal and external) which could cause corrosion or stress corrosion.

3. Prevention of induced stresses due to storage fixture constraints.

H. Periodic Inspection and Periodic Recertification

An inspection and recertification plan shall be developed to schedule and accomplish the necessary periodic inspections and recertification. It shall be based on design material usage and other appropriate considerations. A more thorough coverage of these requirements is contained in paragraph J. below.

I. Fabrication

Established and verified procedures shall be used to preclude damage to or material degradation of the pressure vessel during processing and fabrication. These procedures shall include detailed fabrication instructions and controls to properly guard against processing damage or other structural degradation.

J. Quality Assurance (for new pressure vessels)

The quality assurance system shall ensure that materials, parts, subassemblies, assemblies, and completed tanks with associated accessories conform to applicable drawings and specifications; that no damage or degradation has occurred during fabrication, processing, inspection, testing, shipping, storage or operational use; and that defects which could cause failure are detected, evaluated, and corrected. The system should focus on control and prevention of defects as well as their detection. As a minimum, the following quality control considerations shall be made with selected action documented in a control plan:

1. Appropriate inspection points and nondestructive inspection techniques, shall be selected to verify and ensure compliance with specifications. In choosing inspection points and techniques, consideration should be given to material, structural configuration, accessibility for inspection, and predicted size, location, and characteristics of critical initial flaws. In choosing nondestructive testing techniques and methods, consideration should be given to the capability of reliably detecting existing flaws and use in future periodic re-inspections.

2. Procedures shall be established to ensure that unplanned events which could be detrimental to pressure vessel integrity are reported and evaluated through formal review.

3. Procedures for identifying the certified characteristics of each pressure vessle shall include appropriate specifications, such as allowable working pressure, proof pressure,

design burst pressure, drawing number, control plan number, etc. Any stamping, marking, or tagging shall be accomplished in a manner which does not degrade the structural quality of the pressure vessel.

4. Records of the Following:

   a. A time, cycle, and temperature history of tank pressurizations for both tests and operations including the fluid media used.

   b. Descriptions of any storage or maintenance conditions and analyses supporting the design and modification which might influence future use capability.

   c. The design and operational criteria of the pressure vessel.

   d. Initial and subsequent periodic inspections and test date records with appropriate sign-off signifying certification status.

5. Provisions for periodic inspection of the pressure vessel and its control documents by the pressure vessel operator, safety engineer, or other cognizant agencies.

K. Protective Devices

Provision shall be included in the operations and configuration control plan for the use of the devices to limit the maximum pressure imposed on medium weight pressure vessels to that pressure consistent with the maximum allowable working pressure established in the design analysis. Pressure relief capability shall be provided for pressure vessels whose contents or operation are capable of causing an increase in internal pressure. For those vessels whose pressure can only remain constant or monotonically decrease, active relief capability is not required provided pressure fluctuations due to external ambient temperature changes do not cause the maximum allowable or safe operating pressure to be exceeded. Where mechanical protective devices are required, the size selected shall accommodate the maximum possible internally generated gas flow without increase in pressure.

L. Compliance with the intent of this standard will constitute certification for existing medium weight pressure vessels which in the past have not been certifiable under industrial standards but which essentially identical pressure vessels have a significant history of successful operation. The following data are required for such certification:

1. A design stress, fatigue or Fracture Mechanics type analysis utilizing approved standards, i.e., ASME, DOT, ASTM, etc., for material properties or

2. Material property qualification data or burst test data that substialyes the pressure vessel integrity.

3. A thorough NDT inspection

4. A verification as required by VI. D. above.

5. A history of operation of several essentially identical pressure vessels which demonstrate significant successful use in the intended application.

In no case may an existing medium weight pressure vessel be certified to a factor of safety of less than 2.5.

Existing pressure vessels which are certified to the intent of this standard shall only be operated using written and approved procedures and only within the limits specified in the recertification documentation.